NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL NOTE 3039

EXPERIMENTAL STRESS ANALYSIS OF STIFFENED CYLINDERS WITH CUTOUTS

PURE TORSION

By Floyd R. Schlechte and Richard Rosecrans

Langley Aeronautical Laboratory
Langley Field, Va.

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SUMMARY

Torsion tests were made on a cylindrical semimonocoque shell of circular cross section. The cylinder was first tested without a cutout, and then with a rectangular cutout which was successively enlarged through six sizes varying from 30° to 130° in circumference and from 1 to 2 bays in length. Strain measurements were made with resistance-type wire strain gages near the cutout on the stringers, the skin, and the rings for each size of cutout, and the stresses obtained are presented in tables.

INTRODUCTION

The problem of finding the stress distribution around cutouts in shell structures has been important for a long time in the design of aircraft. Nevertheless, good experimental data which cover a wide range of design parameters have not as yet been published. In reference 1, some data for stresses around cutouts are given for a series of tests of a cylinder loaded by torque or direct shear. Only shear stresses are given for the tests of the cylinder under torque loading, and only axial stresses are given for the tests with direct shear loading. Both shear stresses and stringer stresses are presented in reference 2 for similar tests of a cylinder having a pair of cutouts, one on either side; but the effect of change of cutout size was not investigated. In references 3 to 5, stringer strains but only a limited number of shear strains are presented for a series of pure bending tests of cylinders with cutouts.

In order to provide further basic experimental data, an extensive investigation of a semimonocoque circular cylinder having a cutout of varying size and subjected to various loading conditions has been undertaken. This investigation is intended to yield a fairly detailed picture of stringer stress, shear in the skin, and ring stresses, in the neighborhood of the cutout for a cylinder loaded in torsion, pure bending, and combined shear and bending. The present paper gives the results for pure torsional loading.

TEST SPECIMEN AND PROCEDURE

The test cylinder, which is shown in figure 1, consisted of a 24S-T aluminum-alloy skin 0.051 inch thick, 36 external $3/4 \times 3/4 \times 3/32$ angle stringers with cross-sectional area of 0.1373 square inch, and 8 equally spaced 24S-T aluminum-alloy Z-section rings with cross-sectional area of 0.4413 square inch. The rings were made of 1/8-inch sheet and were 2 inches deep with 1-inch flanges. After an initial test of the cylinder without a cutout, the series of cutout tests began with a cutout 1 bay in length by 30° in circumference. In four succeeding tests, the cutouts were 1 bay long and varied up to 130° in circumference. A final test was made with a cutout 2 bays long by 130° in circumference. The size of the cutout for each test is given in table 1.

The cylinder was mounted on a heavy ring which was bolted to a rigid support. Load was applied to a steel bulkhead at the tip by means of a hydraulic jack acting on a torque-loading frame. (See fig. 2.)

Baldwin SR-4 wire strain gages mounted near the cutout on the stringers, skin, and rings were used for obtaining all the strain measurements. Type A-12 gages were used on the stringers and rings and type AR-1 rosette gages were used on the skin. Typical gage mountings are shown in figure 3. Stringer gages were mounted along the inside corner of the stringer angle, either at the rings or halfway between rings. Rosette gages were mounted either halfway between rings or $1\frac{1}{4}$ inches from a ring. In each rosette, two gages mounted at angles of 45° and 135° to the axis of the cylinder were used to measure the shear strain. Ring gages were mounted in groups of three under the points where stringers crossed the rings, and were mounted near the neutral axis of the ring cross section and on both flanges. The gage pattern in figure 4(a) shows the location of all the strain gages used in tests 2 to 6. The angular coordinate θ is measured from the center line of the cutout. All the gages shown were used in the test with a 30° cutout 1 bay long. For successive tests with a cutout 1 bay long, the cutout was enlarged by removing panels symmetrically located on either side of the longitudinal center line. All gages not cut away by enlarging the cutout were used in the next test. The gage pattern for test 7, with a 130° cutout 2 bays long, is shown in figure 4(b).

In each test, the maximum load was chosen to make the most highly strained gage indicate about 10,000 psi tension or compression. This value was well below the buckling load in each test but was considered high enough to avoid the large relative errors associated with measurements of very small strains.

About 300 to 400 gages were read in each test, but the equipment available permitted only 80 gages to be read at one time. The procedure was as follows: A group of approximately 80 gages was read at each of four successively higher loads; then the first load was repeated as a check. If for some gages the original reading and the check reading differed by more than about 100 psi the data for those gages were rejected and a test was performed for those gages only. Testing continued until satisfactory checks were obtained. If the temperature varied more than 1° F during a test run, the entire run was repeated. The reruns required only a small portion of the total testing time. After satisfactory data were obtained for a group of gages, another set of about 80 gages was read and the testing continued until all the gages had been read.

DATA REDUCTION AND ACCURACY

For each test, load was plotted against strain for each gage and the slope of a straight line through the test points determined the value taken as the strain at the maximum test load. Strains were converted to stresses with Young's modulus taken as 10,600,000 psi and the shear modulus as 4,000,000 psi. Tension is considered positive for normal stresses and a clockwise tip torque produces positive shear stresses in the skin.

All results were referred to one quadrant because of symmetry; consequently, when possible, data from gages in various quadrants were averaged. The strain-gage layouts shown in figure 4 indicate how much averaging was possible. The final stresses were all reduced to correspond to a torque of 60,000 inch-pounds, which was the maximum load for test 7.

Errors in measuring the applied load include an uncertainty of 1 percent in the jack load and a small amount of friction in the loading frame. In addition, the strain gages may have inaccuracies of 200 psi at the loads of the actual tests or 3 percent, whichever is larger. However, the agreement between results in four quadrants indicated that the strain-gage errors were usually considerably less than these amounts, and the results presented are better than individual gage data because of the averaging. The applied torque calculated from the jack load and that calculated from the shear stresses always agreed within about 5 percent, and usually within 2 percent.

RESULTS

Experimental stresses obtained by the procedures described in the preceding sections are presented in tables 2 to 7. The actual maximum load used in each test is noted in the tables. Stress distributions for all six of the cutout tests are given in these tables, each of which has four parts. Stringer stresses are given in part (a) of each table and shear stresses are presented in part (b). An initial test of the cylinder without a cutout showed that the stresses were very close to those given by elementary theory. Consequently, in all of the cutout tests, "shear stresses due to cutout only" were calculated by subtracting the average shear stress for no cutout, as determined by the Bredt formula, from the measured stresses. "Shear stresses due to cutout only" are presented in part (c). Finally, the ring stresses are contained in part (d) of each table.

General trends of the stringer stresses and shear stresses around the cutout are shown pictorially in figures 5 and 6. Stresses corresponding to the 30° cutout are given in figure 5 and stresses for the 90° cutout are given in figure 6. Each figure has three parts corresponding to sections (a), (b), and (c) of the tables. The test points, which are represented by the height of the heavy vertical lines, are joined by straight lines to give a pictorial view of the stress field. On the figures showing shear stresses the lines joining points on opposite sides of the coaming stringer near the cutout have been dashed because a straight line is not very accurate in this region.

CONCLUDING REMARKS

Stresses obtained in a series of torsion tests of a stiffened cylindrical shell with a cutout are presented in tables for six different sizes of the cutout. The data presented are intended primarily to serve as a check on methods of analysis or as a guide to the development of such methods. Consequently, no attempt has been made in this paper to interpret the data or draw conclusions therefrom.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., August 24, 1953.

REFERENCES

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2. Henson, G. S.: Stress Distribution Near a Rectangular Cut-Out in a Reinforced Circular Cylinder Due to Direct Shear Loading and Torque. Part I – Test Results. Rep. No. 51, College of Aero., Cranfield (British), Jan. 1952.

3. Hoff, N. J., and Boley, Bruno A.: Stresses in and General Instability of Monocoque Cylinders With Cutouts. I – Experimental Investigation of Cylinders With a Symmetric Cutout Subjected to Pure Bending. NACA TN 1013, 1946.

4. Hoff, N. J., Boley, Bruno A., and Viggiano, Louis R.: Stresses in and General Instability of Monocoque Cylinders With Cutouts. IV – Pure Bending Tests of Cylinders with Side Cutout. NACA TN 1264, 1948.

5. Hoff, N. J., Boley, Bruno A., and Mele, Joseph J.: Stresses in and General Instability of Monocoque Cylinders With Cutouts. VII – Experimental Investigation of Cylinders Having Either Long Bottom Cutouts or Series of Side Cutouts. NACA TN 1962, 1949.

TABLE 1.- CUTOUT SIZE

Test	Length of cutout, bays	Width of cutout, deg
1	None	None
2	1	30
3	1	50
4	1	70
5	1	90
6	1	130
7	2	130

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 300,000 INCH-POUNDS)

(a) Stringer stresses, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
		0	146		52	
15	31	1,419	595		120	
	0	295	288		139	
	0	3	47		108	
45	38	-105	-68		42	
	32	-114	-101		14	
	15	-125	-107	-18	-27	
75	32	-78	-48		-25	
	42	-23	-16	-36	-37	
105						

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 300,000 INCH-POUNDS) - Continued

(b) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	0	6 (left)	6 (right)	12	18 (left)	18 (right)	24	30	36
			1,069	1,127					
			1,338	1,084			921		882
15									
	1,102	1,138	487	705					
	1,367	1,183	628	614			809		854
	1,248	1,177	735	709					
45									
	1,095	1,084	764	805		778	799		827
	971	922	834	864					
	868	865	868	906	890	817	861		829
75									
	802	808	863		908				
	784	757	798	879	848	854	886		882
105									
	807	792	834		833				
135									
	838	792	805				869		
			821						
165									
	849	836							

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TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 300,000 INCH-POUNDS) - Continued

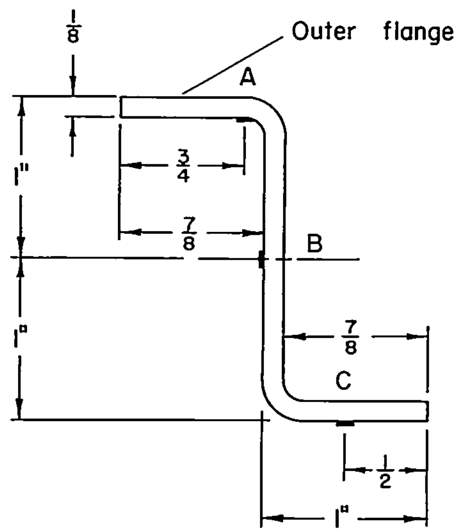
(c) Shear stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	0	6	6	12	18	18	24	30	36
			237	295					
			506	252			89		50
15									
	370	306	-345	-127					
	535	351	-204	-218			-23		22
	416	345	-97	-123					
45									
	263	252	-68	-27		-54	-33		-5
	139	90	2	32					
	36	33	36	74	58	-15	29		-3
75									
	-30	-24	31		76				
	-48	-75	-34	47	16	22	54		50
105									
	-25	-40	2		1				
135									
	6	-40	-27				37		
			-9						
165									
	17	4							

TABLE 2.- STRESSES AROUND CUTOUT OF 30° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 300,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	104	192	142
15	74	385	438
25	-17	441	449
35	-140	322	344
45	-185	141	192
55	-146	-11	27
65	-73	-97	-106
75	21	-162	-186
85	68	-148	-199
95	121	-115	-167

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 252,000 INCH-POUNDS)

(a) Stringer stresses, psi

Distance from center line of cutout, in.

θ, deg	0	6	12	18	24	30
		0	50		66	
15		0	322		194	
	0	2,150	857		246	
	40	324	332		218	
45	63	-112	-26		148	
	20	-219	-177		33	
	0	-221	-197	-54	-18	
75	13	-179	-158		-59	
	5	-33	-42	-111	-90	
105						

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 252,000 INCH-POUNDS) - Continued

(b) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	0	6	6	12	18	18	24	30	36
			967	1,048					
			1,032	1,062			956		901
15			1,488	1,079					
	1,626	1,504	296	565			809		863
	1,814	1,554	535	519					
45	1,534	1,446	694	697		750	749		815
	1,231	1,220	809	866					
	1,015	993	849	944	945	830	828		847
75	823	824	913		974				
	710	704	895	930	926	912	914		883
105									
	766	757	867		856				
135	839	812	817				869		
			824						
165	877	862							

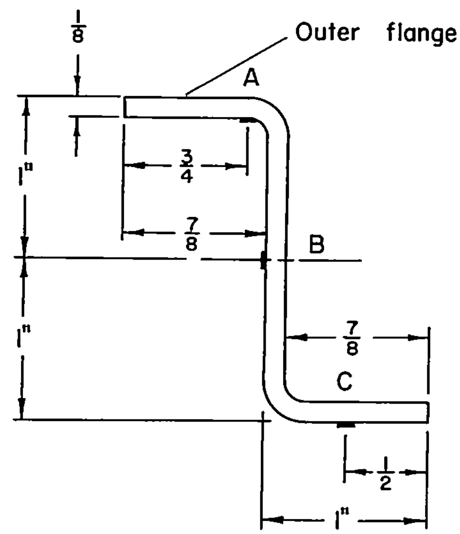
TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 252,000 INCH-POUNDS) - Continued

(c) Shear stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in.: 0	6 (left of line)	6 (right of line)	12	18 (left of line)	18 (right of line)	24	30	36
	+		135	216					
15			200	230			124		69
			656	247					
	794	672	-536	-267			-23		31
	982	722	-297	-313					
45	702	614	-138	-135		-82	-83		-17
	399	388	-23	34					
	183	161	17	112	113	-2	-4		15
75	-9	-8	81		142				
	-122	-128	63	98	94	80	82		51
105									
	-66	-75	35		24				
135	7	-20	-15				37		
			-8						
165	45	30							

TABLE 3.- STRESSES AROUND CUTOUT OF 50° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 252,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	3	245	250
15	81	695	633
25	-49	751	950
35	-201	734	768
45	-317	377	464
55	-291	64	128
65	-158	-180	-169
75	2	-291	-353
85	119	-315	-418
95	227	-259	-380

TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 204,000 INCH-POUNDS)

(a) Stringer stresses, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
		0	39		68	
15		0	162		250	
		0	479		360	
	131	2,890	1,130		384	
45	16	302	351		323	
	19	-298	-182		153	
	25	-399	-339	-44	2	
75	12	-346	-331		-83	
	28	-157	-134	-187	-170	
105						

TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 204,000 INCH-POUNDS) - Continued

(b) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	0	6	6	12	18	18	24	30	36
			874	849					
			897	889			977		933
15									
			1,041	1,032					
			1,644	1,038			815		858
	2,211	2,049	-53	427					
45									
	2,326	1,972	401	428		641	682		750
	1,775	1,717	682	711					
	1,290	1,296	849	901	895	773	765		746
75									
	927	956	932		1,012				
	631	593	945	1,003	1,007	923	928		844
105									
	659	623	924		878				
135									
	806	724	790				854		
			774						
165									
	911	917							

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TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 204,000 INCH-POUNDS) - Continued

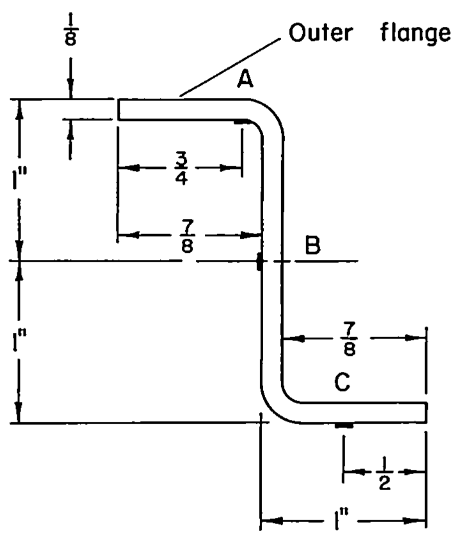
(c) Shear stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	0	6 (left of edge)	6	12	18 (left of edge)	18 (right of edge)	24	30	36
			42	17					
			65	57			145		101
15			209	200					
			812	206			-17		26
	1,379	1,217	-885	-405					
45	1,494	1,140	-431	-404		-191	-150		-82
	943	885	-150	-121					
	458	464	17	69	63	-59	-67		-86
75	95	124	100		180				
105	-201	-239	113	171	175	91	96		12
	-173	-209	92		46				
135									
	-26	-108	-42				22		
165			-58						
	79	85							

TABLE 4.- STRESSES AROUND CUTOUT OF 70° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 204,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	-159	281	352
15	-283	793	905
25	-192	1,163	1,331
35	-322	1,116	1,434
45	-384	876	969
55	-431	316	413
65	-314	-132	-139
75	-94	-436	-503
85	154	-535	-719
95	341	-500	-730

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 156,000 INCH-POUNDS)

(a) Stringer stresses, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
		0	44		77	
15		0	129		287	
		0	287		425	
		0	703		560	
45	147	3,917	1,432		530	
	25	260	321		371	
	37	-535	-347	85	133	
75	33	-583	-550		-92	
	37	-342	-330	-367	-277	
105						

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 156,000 INCH-POUNDS) - Continued

(b) Shear stresses, psi

θ, deg	Distance from center line of cutout, in.								
	0	6	6	12	18	18	24	30	36
			789	680					
			815	750			982		982
15									
			896	875					
			1,093	1,092			891		886
			1,928	1,117					
45									
	2,979	2,768	-362	324		642	673		776
	2,994	2,479	294	364					
	2,107	1,973	686	753	764	678	688		729
75									
	1,331	1,337	926		1,047				
	507	547	1,027	1,144	1,139	965	1,006		860
105									
	455	474	952		955				
135									
	703	677	829				878		
			770						
165									
	936	925							

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 156,000 INCH-POUNDS) - Continued

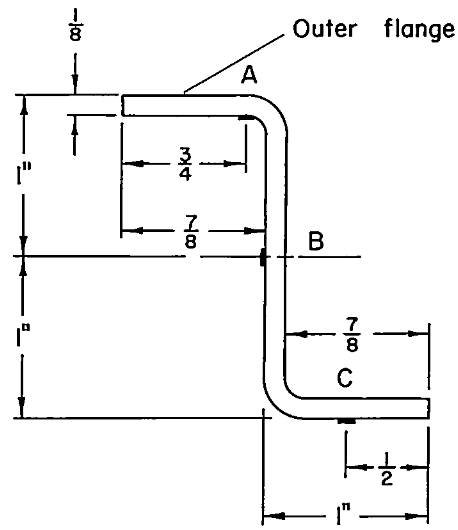
(c) Shear stresses due to cutout only, psi

Distance from center line of cutout, in.

θ, deg	0		6	12		18	24	30	36
			-43	-152					
			-17	-82			150		150
15			64	43					
			261	260			59		54
			1,096	285					
45	2,147	1,936	-1,194	-508		-190	-159		-56
	2,162	1,647	-538	-468					
	1,275	1,141	-146	-79	-68	-154	-144		-103
75	499	505	94		215				
105	-325	-285	195	312	307	133	174		28
	-377	-358	120		123				
135	-129	-155	-3				46		
			-62						
165	104	93							

TABLE 5.- STRESSES AROUND CUTOUT OF 90° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 156,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	-271	290	433
15	-620	891	1,191
25	-815	1,380	1,751
35	-500	1,648	1,919
45	-576	1,406	1,858
55	-488	909	991
65	-441	148	150
75	-191	-448	-572
85	101	-812	-1,064
95	458	-870	-1,191

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 90,000 INCH-POUNDS)

(a) Stringer stresses, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
		0	23		87	
15		0	151		372	
		0	273		556	
		0	355		749	
45		0	530		919	
		0	1,147		873	
	-467	6,462	2,082	1,021	756	
75	106	205	103		368	
	141	1,113	-1,440	-685	499	
105						

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED

BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD,

90,000 INCH-POUNDS) - Continued

(b) Shear stresses, psi

Distance from center line of cutout, in.

θ, deg	0	6	6	12	18	18	24	30	36
			551	324					
			573	380			884		1,044
15									
			645	516					
			748	756			887		915
			709	1,108					
45									
			1,424	1,473		860	873		744
			2,787	1,390					
	5,191	4,734	-1,077	55	613	575	607		656
75									
	4,498	3,675	129		640				
	1,291	1,189	1,115	1,286	1,346	972	923		761
105									
	88	77	1,189		1,317				
135									
	220	179	967				1,024		
			698						
165									
	924	813							

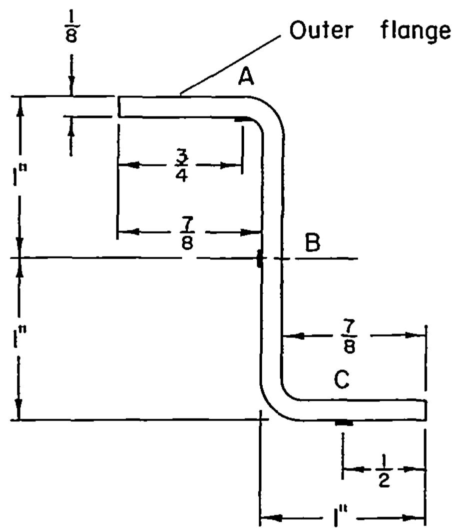
TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 90,000 INCH-POUNDS) - Continued

(c) Shear stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in. 0	6		12	18		24	30	36
			-281	-508					
			-259	-452			52		212
15			-187	-316					
			-84	-76			55		83
45			-123	276					
			592	641		28	41		-88
			1,955	558					
	4,359	3,902	-1,909	-777	-219	-257	-225		-176
75	3,666	2,843	-703		-192				
	459	357	283	454	514	140	91		-71
105									
	-744	-755	357		485				
135	-612	-653	135				192		
165			-134						
	92	-19							

TABLE 6.- STRESSES AROUND CUTOUT OF 130° BY 1 BAY IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 90,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	-443	334	516
15	-1,197	894	1,526
25	-1,894	1,378	2,433
35	-2,208	1,864	3,065
45	-1,855	2,237	3,253
55	-795	2,469	2,783
65	-569	1,648	2,129
75	-173	679	337
85	-27	-516	-1,135
95	461	-1,505	-2,113

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 60,000 INCH-POUNDS)

(a) Stringer stresses, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	18	24	30
			0	32		0
15			0	166		509
			0	265		848
			0	466		1,124
45			0	661		1,410
			0	1,537		1,378
	-9	4,543	9,812	3,685	1,865	1,473
75	-233	350	1,378	1,182		806
	1,378	1,081	-1,495	-1,892	-784	-615
105						

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 60,000 INCH-POUNDS) - Continued

(b) Shear stresses, psi

θ, deg	Distance from center line of cutout, in.							
	0	6	12		18	24		30
	+			362	0			
				412	219			1,030
15								
				507	313			
				663	713			927
				1,021	1,160			
45								
				1,715	1,879		991	950
				3,749				
	3,466	3,806	3,697	-1,475	-58	408	503	453
75								
	4,197	4,347	3,131	-511		144		
	1,958	2,097	1,792	1,169	1,112	1,257	746	684
105								
	441	585	531	1,483		1,514		
135								
	268	74	227		1,051			
	391							
165								
		453	268					

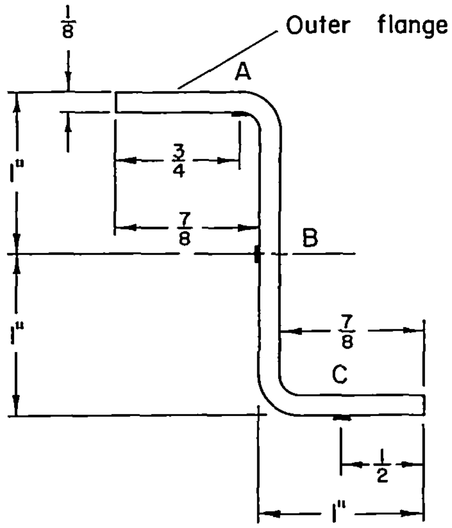
TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 60,000 INCH-POUNDS) - Continued

(c) Shear stresses due to cutout only, psi

θ, deg	Distance from center line of cutout, in.: 0	6	12	12	18	24	24	30
				-470	-832			
				-420	-613			198
15								
				-325	-519			
				-169	-119			95
				189	328			
45								
				883	1,047		159	118
				2,917				
	2,634	2,974	2,865	-2,307	-890	-424	-329	-379
75								
	3,365	3,515	2,299	-1,343		-688		
	1,126	1,265	960	337	280	425	-86	-148
105								
	-391	-247	-301	651		682		
135								
	-564	-758	-605		219			
	-441							
165								
		-379	-564					

TABLE 7.- STRESSES AROUND CUTOUT OF 130° BY 2 BAYS IN CYLINDER LOADED BY TORQUE OF 60,000 INCH-POUNDS (ACTUAL TORQUE LOAD, 60,000 INCH-POUNDS) - Concluded

(d) Ring stresses, psi



θ, deg	A	B	C
5	-599	520	583
15	-1,713	635	1,670
25	-2,595	1,484	2,608
35	-2,890	2,094	3,445
45	-3,050	2,597	3,582
55	-1,956	3,042	3,551
65	-2,002	1,590	3,339
75	-838	1,483	1,584
85	-252	106	-242
95	657	-1,288	-1,918

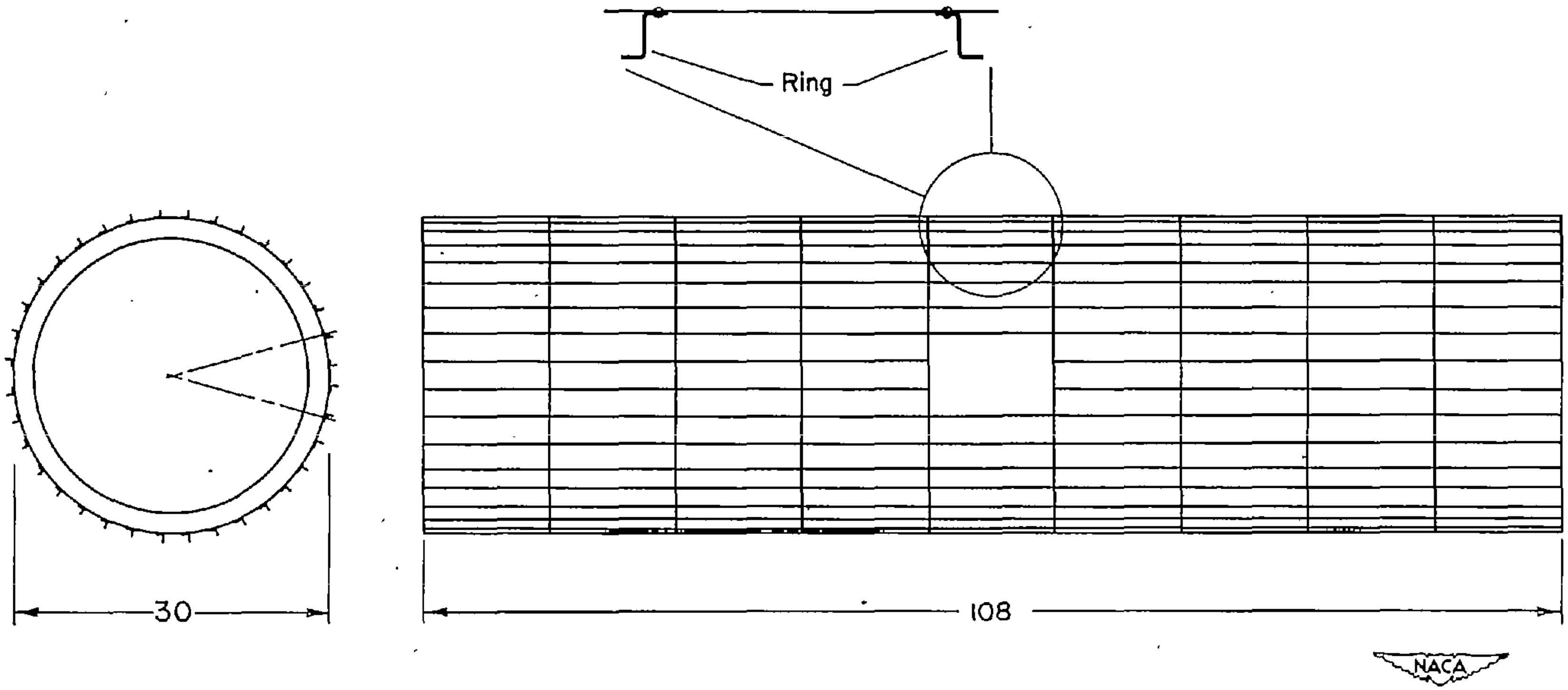
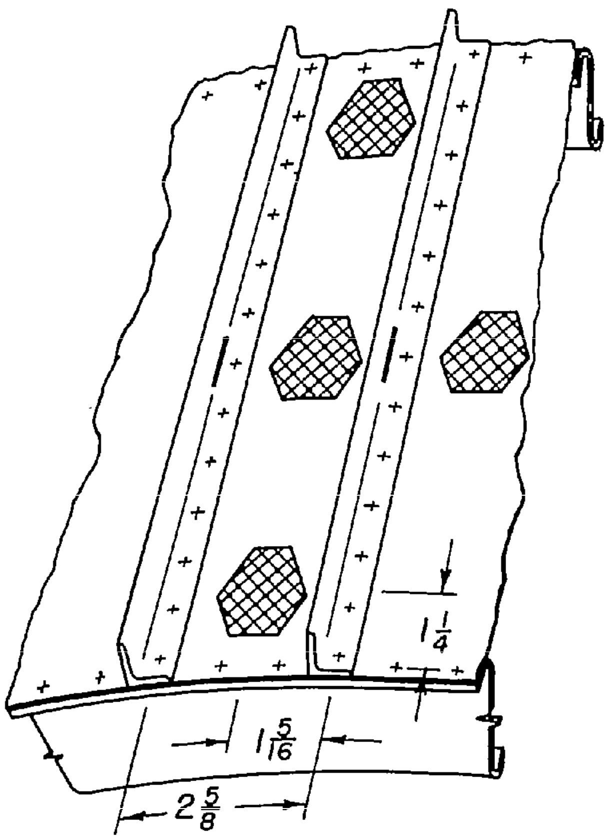
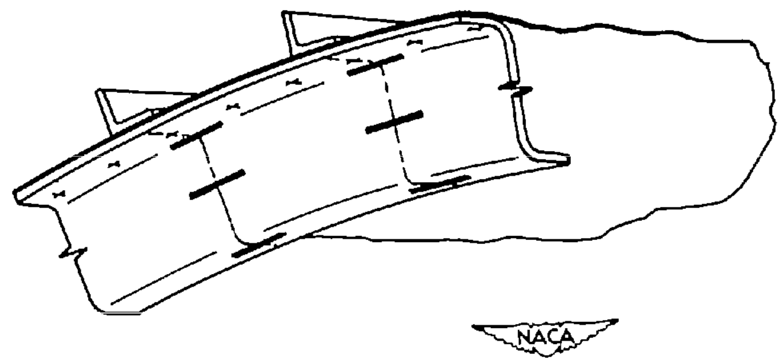


Figure 1.- Test specimen.

Figure 2.- Loading system. L-69889

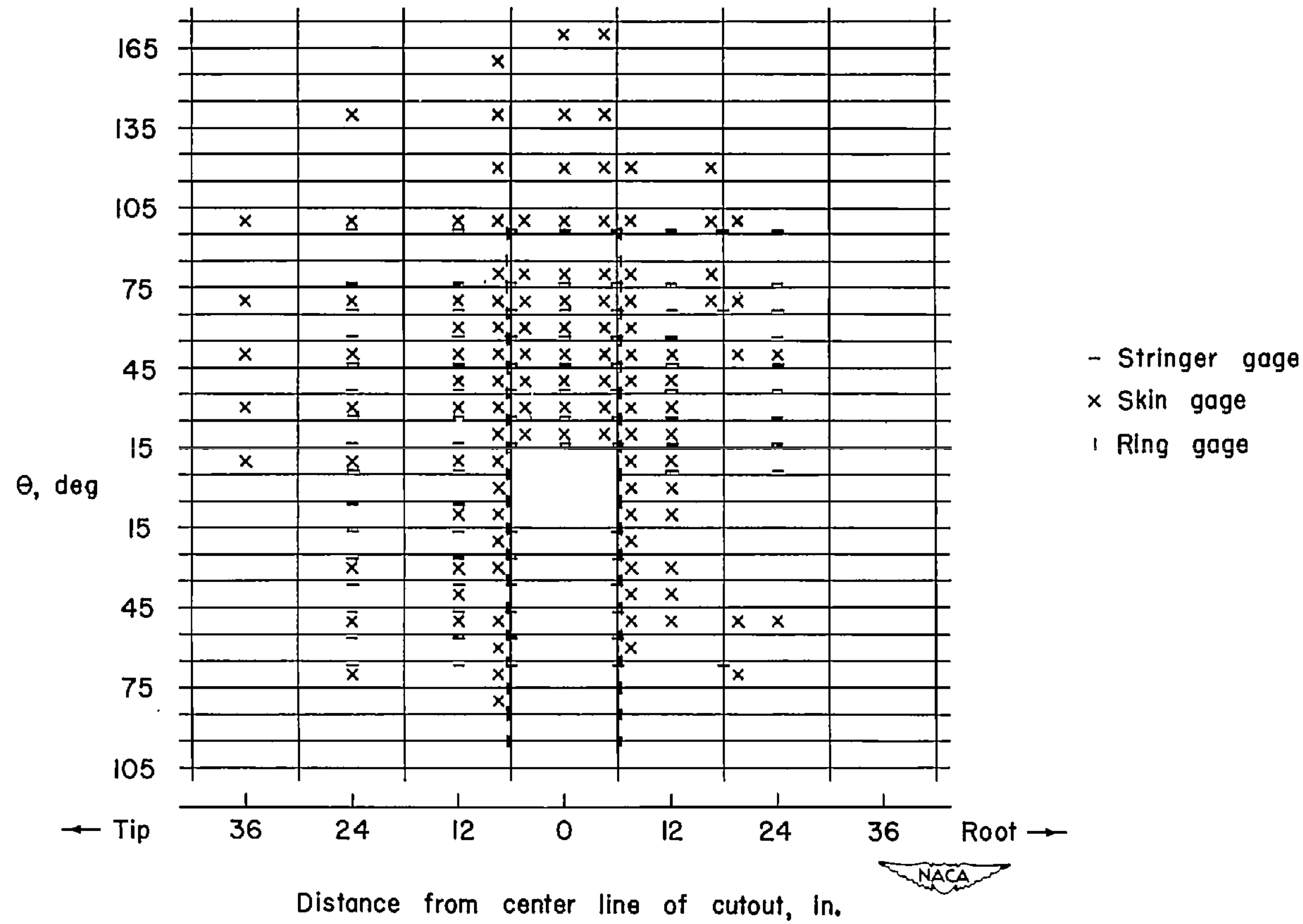


(a) Stringer and skin gages.



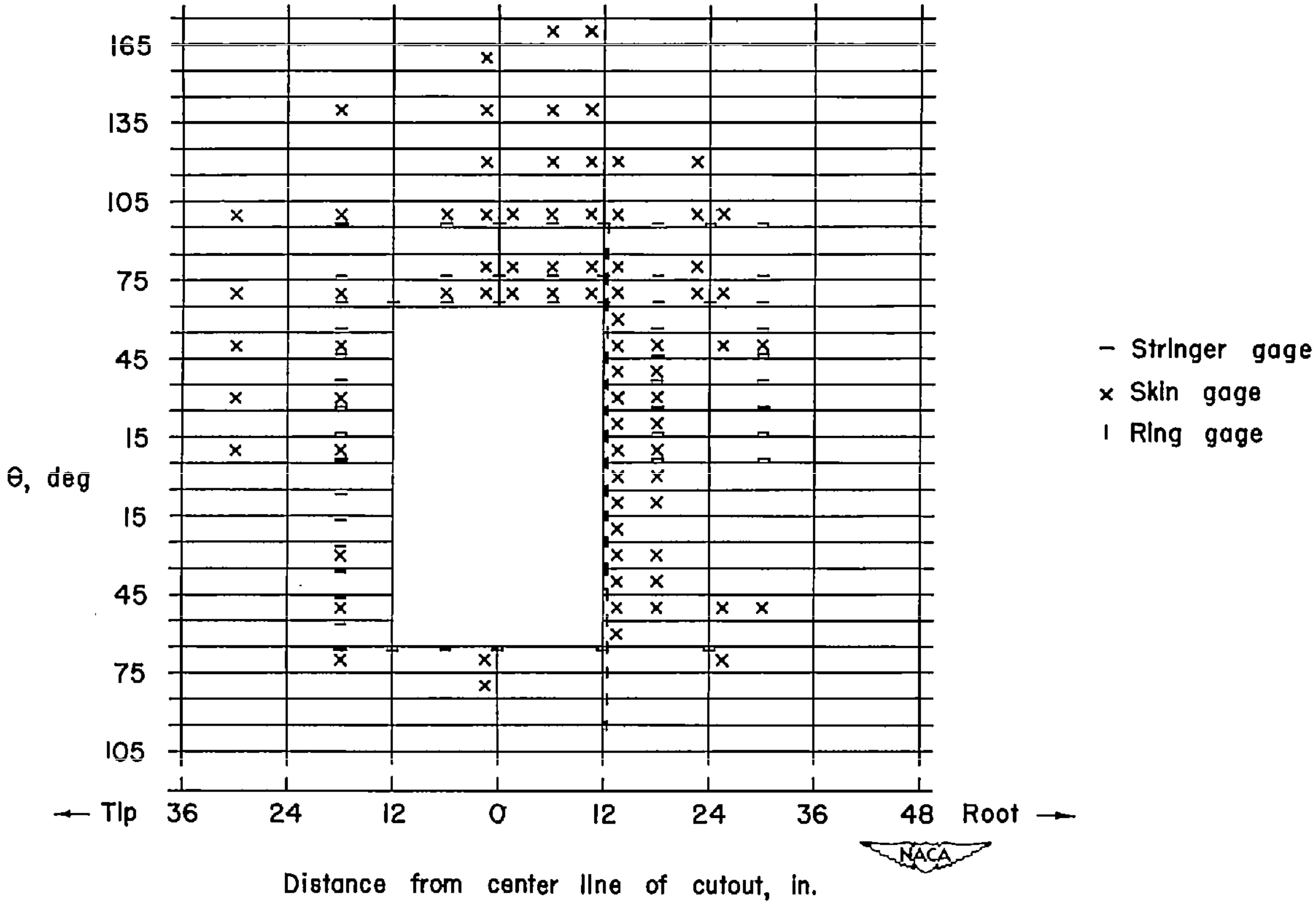
(b) Ring gages.

Figure 3. - Typical gage mountings.



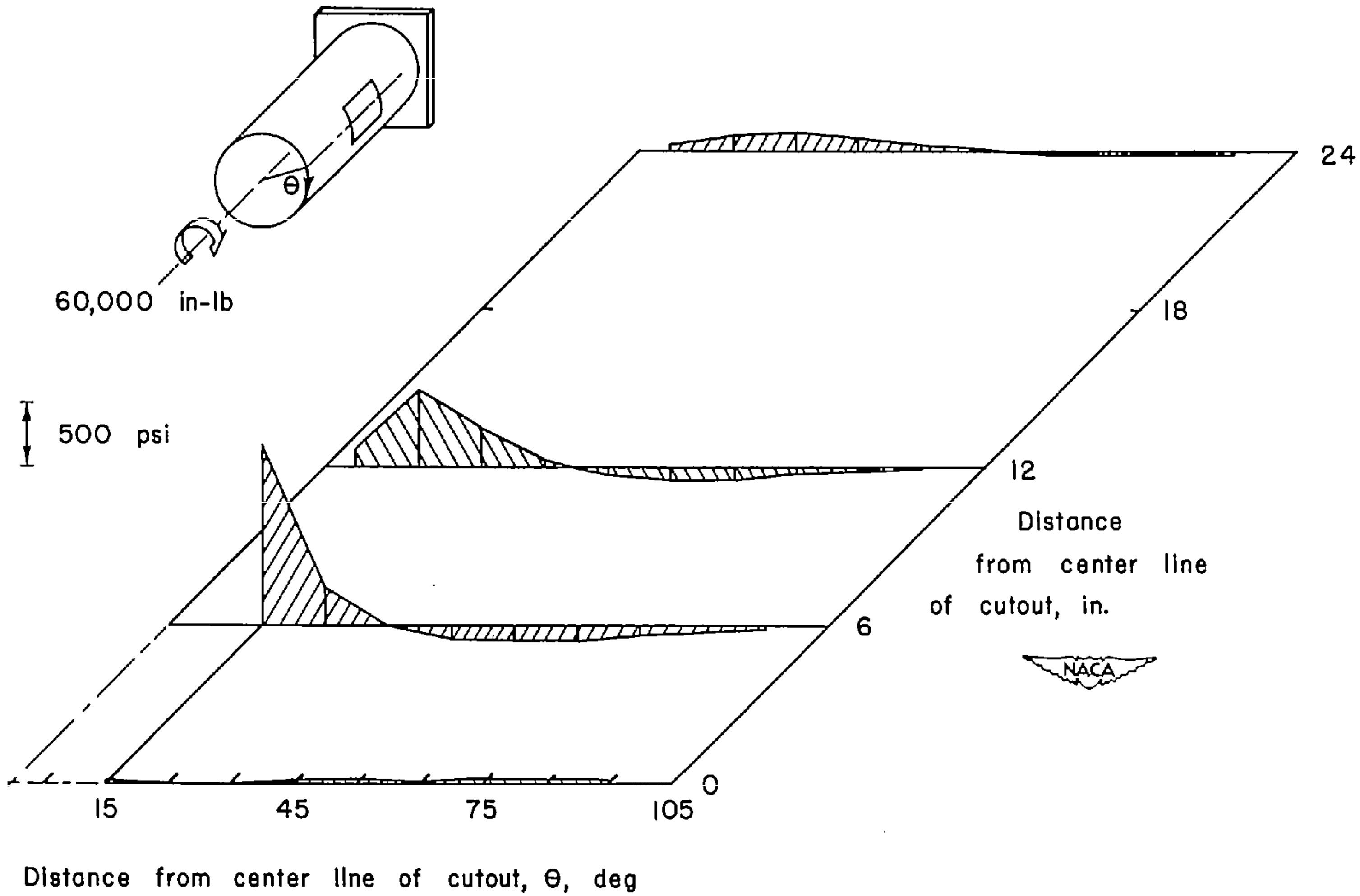
(a) Cutout 1 bay long.

Figure 4.- Gage pattern.



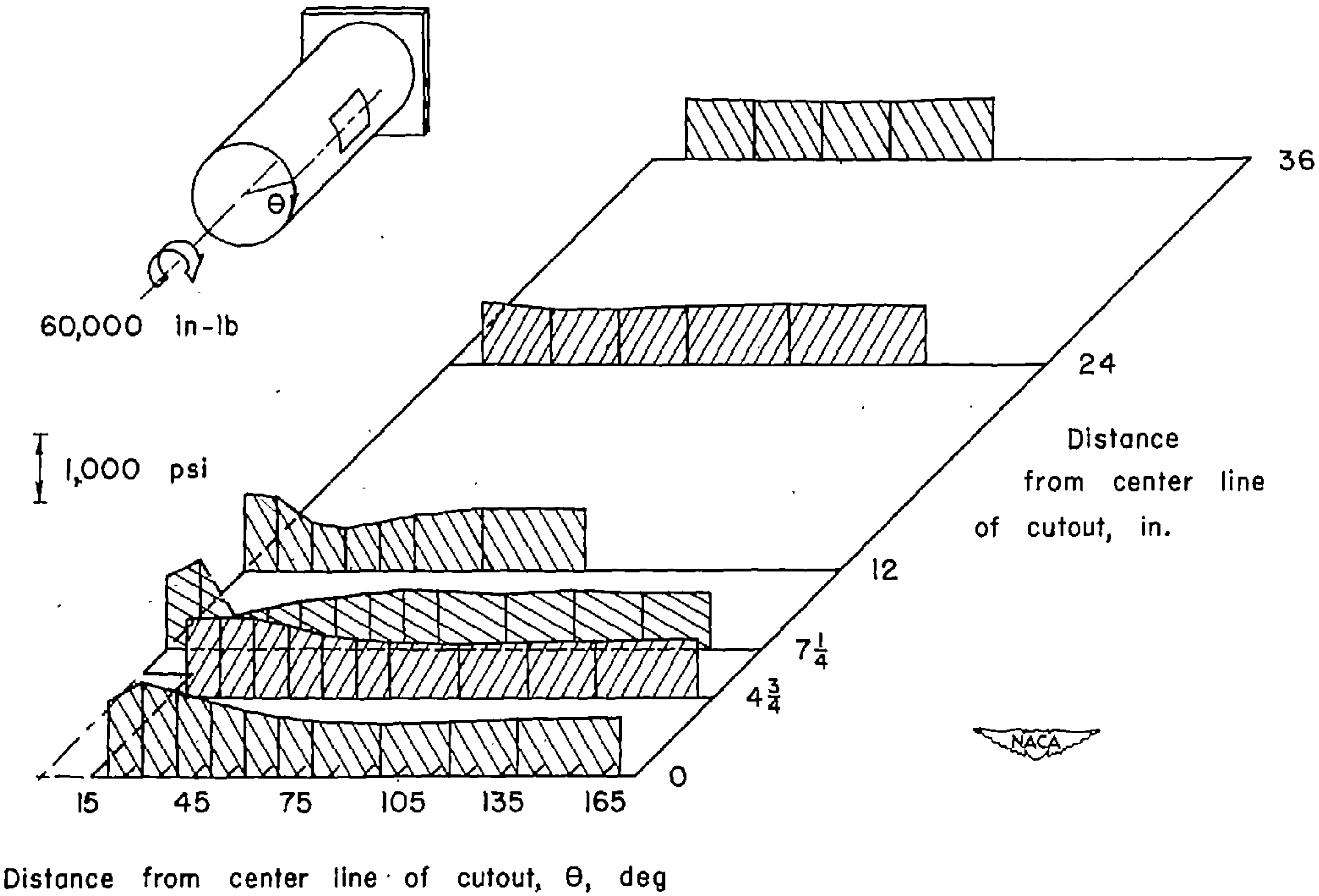
(b) Cutout 2 bays long.

Figure 4.- Concluded.



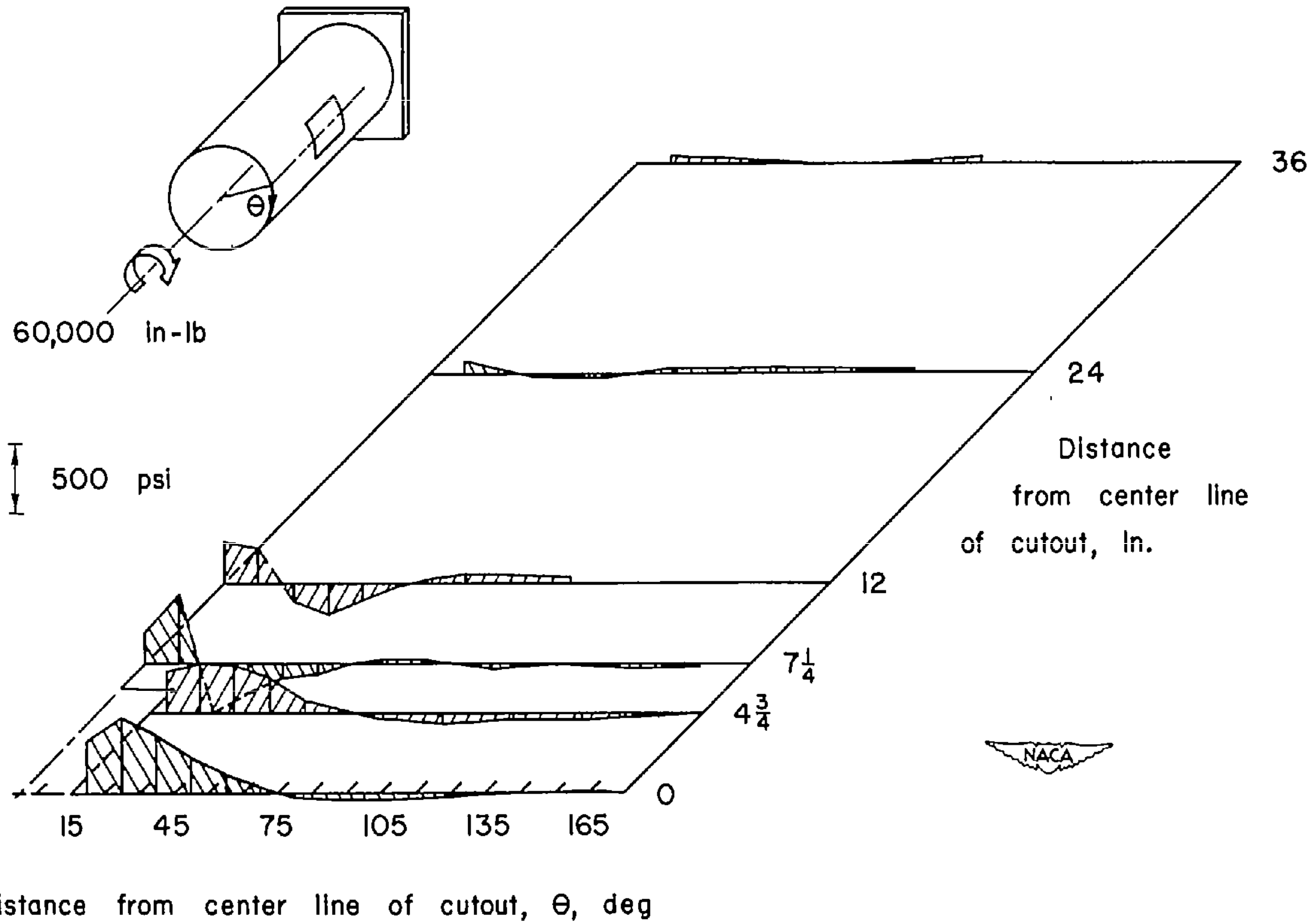
(a) Stringer stresses.

Figure 5.- Stress distribution, 30° cutout.



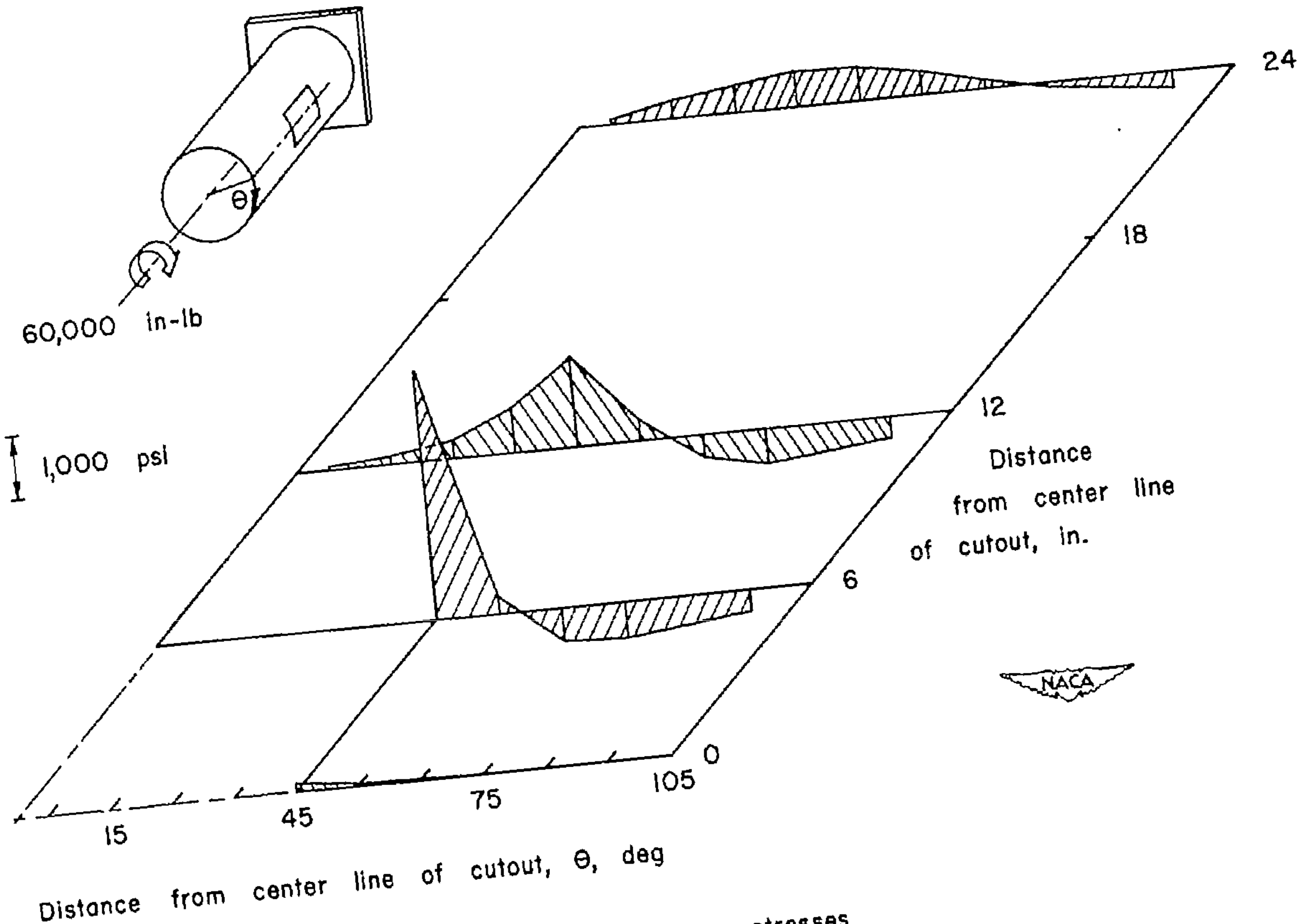
(b) Shear stresses.

Figure 5.- Continued.



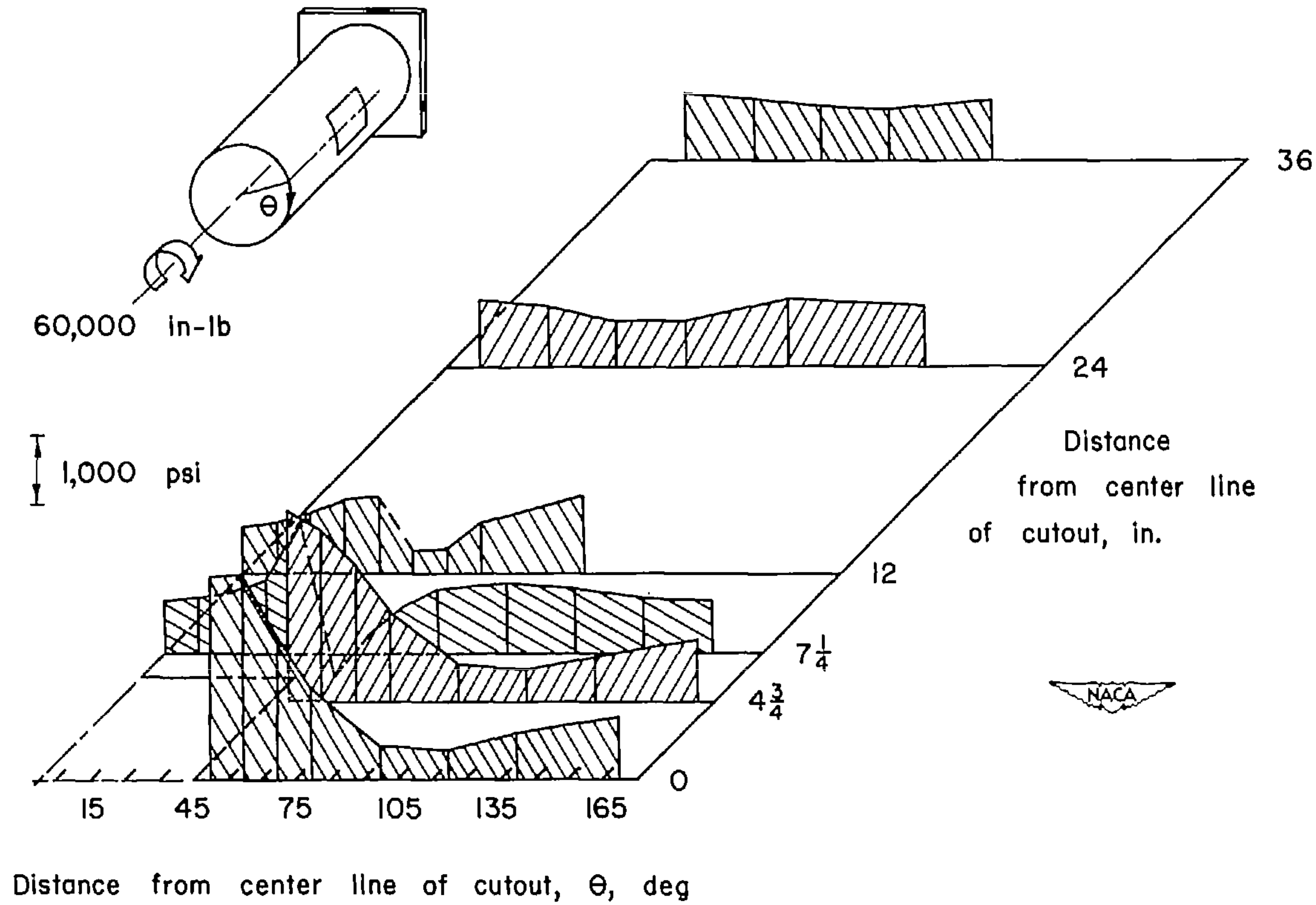
(c) Shear stresses due to cutout only.

Figure 5. - Concluded.



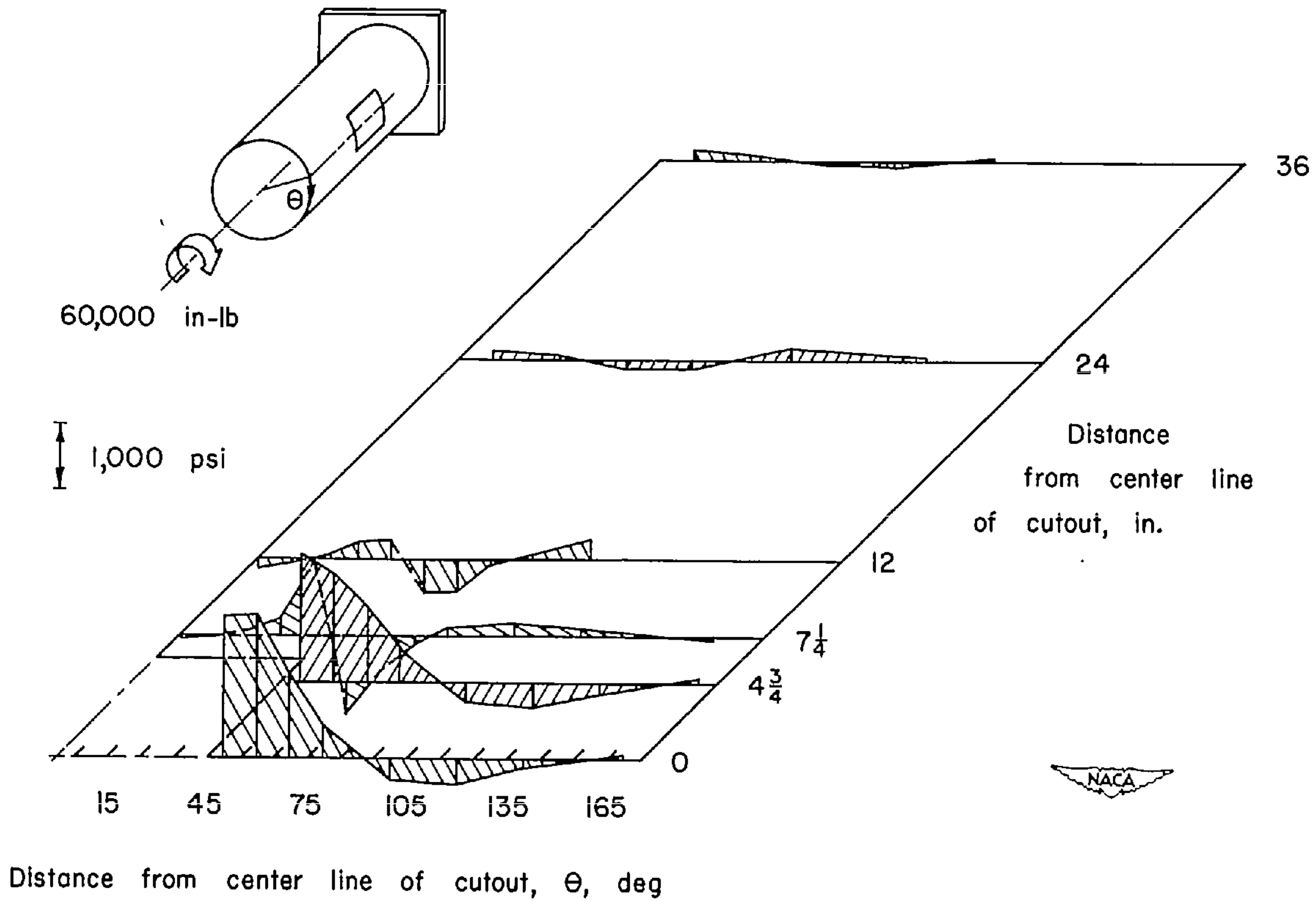
(a) Stringer stresses.

Figure 6.- Stress distribution, 90° cutout.



(b) Shear stresses.

Figure 6. - Continued.



(c) Shear stresses due to cutout only.

Figure 6. - Concluded.

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